U.S. ARMY CORPS OF ENGINEERS
NORTH CENTRAL DIVISION

Help Yourself

A discussion of erosion problems on the Great Lakes and alternative methods of shore protection.

GENERAL INFORMATION PAMPHLET

PAINTED BY WADKINS

Acknowledgements

The U.S. Army Corps of Engineers, North Central Division, compiled and revised these data in cooperation with the Great Lakes States, as a public service. The Government does not guarantee that the methods for combating shore erosion as described herein will be successful in any specific application.

PREFACE

This pamphlet has been prepared to provide owners of private property with technical assistance for the protection of the Great Lakes shoreline from damage due to erosion. The sections of the pamphlet are arranged to enable one to progress in a logical manner from understanding shore erosion to planning considerations for erosion control, to then selecting a type of shore protection. A number of general shore protection designs and costs are presented, with discussion of construction and maintenance guidelines, standard designs, and sample specifications. It is recommended that each section of the pamphlet be read consecutively because information presented in one section will be helpful in understanding material presented in the sections that follow.

U.S. Army Corps of Engineers

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INTRODUCTION

Shore erosion is a major water resource problem on the Great Lakes. Erosion is caused principally by storm induced wave action and associated alongshore currents. Shore erosion problems become critical when high lake levels have submerged the beaches which protect the adjoining highly erodible upland areas. Raised above the beaches, wave forces can work directly on the toe of the bluffs and dunes, resulting in rapid erosion.

The Corps of Engineers, as one of the Federal agencies concerned with beach erosion problems, has constructed many beach erosion control projects along the shores of the Oceans and Great Lakes. The Corps may undertake investigations of beach erosion problems under specific authorizations by Congress, or, for smaller studies, under special continuing authority given by Congress. Under present law, the Corps can provide assistance for protection of public shores, but has no authority to construct erosion control projects aimed solely at protecting private property.

The problem which must be resolved is: How to protect an eroding property? This pamphlet is intended to help private owners evaluate their situation and decide on which course of action should be taken.

In addition to the structural alternatives discussed in the pamphlet, "no action" and relocation should be considered. The benefits associated with no action are saving money and avoiding accelerated erosion on adjacent property with its potential liability problem; however, no protection from damages is provided by this alternative. If property is of sufficient width, homes may be moved back from the eroding shoreline. Long-term expense may be lower with relocation than installing several unsuccessful shore protection structures.

CAUTION. This pamphlet is not intended as a substitute for professional engineering services that are needed to properly design shore protection works. The design of shore protection measures is complex and good engineering principles must be followed. A qualified engineer can help reduce the risk of failure by designing protection for the conditions at a specific problem area.

Severe Erosion at Stickney Ridge, MI., in 1973.

SHORE PROCESSES

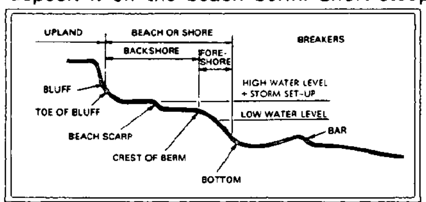
The beach profile is a relatively small physiographic feature whose limits are defined by the effects of waves. As waves approach the shore they react in special ways; they reflect, diffract and refract. The beach then acts as a natural defense against the attack from waves. The first defense against the waves is the sloping nearshore bottom which dissipates the energy,or weakens the force of the deepwater waves.

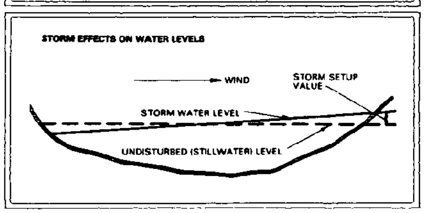
The shoreline erodes from the force of wave action. The erosive energy of a wave is a function of wave height and the depth of the water in which the wave acts. Wave energy is strongest in deep water but its effect is greatest thru the surf zone, from the start of breaking waves to the limit of run up.

The amount of energy delivered to the beach depends on the level of the lake and the storm set up or storm induced temporary rise in lake stage. The offshore depth is one of the most important parameters in the design of shore protection structures. During high lake levels the typical shore becomes a narrow unstable beach at the foot of a steep bluff or dune. Waves attack the toe of the bluff undercutting its face which falls on the beach. Waves wash out the fine bluff material, carry it offshore to deep water, or move it along the shore by littoral currents.

High lake levels change the effects that waves have on the beach profile as shown below. The natural beaches are submerged and waves act directly on the highly erodible backshore. The increased wave action on the beach increases the rate of erosion of the bluff. In the new balance, a beach will reform its equilibrium slope, but the foreshore would be moved landward. During high lake levels beaches may exhibit a steep and rather uniformly sloping profile and thus the effects of storm waves are greatly increased.

Material is moved and redistributed along the beach by the waves and wave generated currents. Long flat waves pick the sand up, move it forward, and deposit it on the beach berm. Short steep waves acting on the beach carry the sand lakeward. The direction of littoral transport depends on the direction of the wave generated energy which impinges upon a shore. Generalized data on storm water set up and the net direction of littoral transport are shown on the map of the Great Lakes on page 6.





Short period fluctuations of the lakes (Storm setup) result from meteorological disturbances and may last from a few hours to a few days. Wind and barometric pressure cause the lake surface to tilt as shown to the left. The amount of storm setup depends on local conditions. These values are shown in ( ) on the map for selected stations on the Great Lakes on page 6. The storm setup values are added to the projected lake levels to determine the design water level for the protective works illustrated in this pamphlet. This computation is described on page 16.

LAKE LEVELS

Levels of the Great Lakes fluctuate from year to year and also from month to month during each year depending upon the volume of water in the lakes. The source of the Great Lakes water is in the rain and snow which fall on the lakes themselves and on the land areas which drain them. When the net supply to one of the lakes exceeds the outflow, its level rises. When the net supply is less than the outflow, its level falls. For example, the lake levels reached record highs in the early seventies because the precipitation, in those years, over the Great Lakes Basin exceeded the basin averages.

Seasonal fluctuations, caused by the annual weather pattern are superimposed upon the long-term variations resulting from extended periods of below or above normal precipitation. During each year, the lake levels consistently fall to their lowest elevation in the winter because most precipitation in the watershed areas during the winter is snow and ice. The lake levels then rise to their highest elevation in the summer when the temperature rises and there is substantial runoff due to melting snow and ice. The probable maximum levels for the summer of 1978 are given in the table below and are generally one to two feet less than the recent record levels.

1978	**Lake Superior**	**Lakes Michigan-Huron**	**Lake St. Clair**	**Lake Erie**	**Lake Ontario**
End of August Elevation	**601.1**	**579.0**	**574.4**	**571.5**	**245.0**
End of May	**600.5**	**578.9**	**574.7**	**572.4**	**246.5**
Low Water Datum	**600.0**	**576.8**	**571.7**	**568.6**	**242.8**

Because of the size of the Great Lakes and the limited discharge capacities of their outflow rivers, extreme high or low levels and flows persist for considerable time after the factors which caused them have changed. Where the outflows from the lakes are controlled by regulatory works as is the case with Lakes Superior and Ontario, the releases of water are made in accordance with the plan for the regulation of the lakes levels and outflows which maintain the lakes within a range of water levels acceptable to all interests concerned. All regulation plans are approved by the Governments of the United States and Canada.

INITIATE ACTION BY ORGANIZATION

Community organization is the key to successful emergency shore protection measures. There are several good reasons for organizing groups of property owners in a coordinated approach to erosion control. Example has shown that where individuals have attempted to go it alone, the results have often been ineffective, individual protective structures have been damaged due to continuing erosion on unprotected adjacent properties (flanked) and failed. A well-planned, coordinated, and properly constructed system of shore protection work extending for a considerable distance will capture economy of scale in construction resulting in a lower cost per lineal foot of protection.

The community, or a group of property owners, should organize its resources to respond to the existing situation. Civil defense directors can provide helpful hints on how to organize your manpower and resources into a unit. An existing property owners association would provide a basis for initial action.

The objective of organization is to prepare and implement a plan for shore protection. This plan may consist of some or all of the following:

- administration—delegation of responsibilities, funding, and accounting.
- preconstruction planning—assessment of the existing situation, inventory of existing shore protection works and their effectiveness, maps of the shoreline area, and establishment of surveillance points for photographs and surveying.
- with the aid of an engineer develop a plan of protection, construction drawings, specifications, and a handbook for maintenance.

PERMIT REQUIREMENTS

Federal and State permits are required prior to the construction of any work in, under, across, or on the banks of navigable waters of the United States. In general, both Federal and State permits are required prior to the initiation of construction of shore protection structures along the shores of the Great Lakes, lakeward of the high water mark. The highwater mark is a specific elevation on each of the Great Lakes which establishes a plane above which Federal permits are not required. State and Federal highwater mark elevations vary on some of the Great Lakes. As a result in some cases a Federal permit may be required where a State permit may not. It is suggested that if there is any doubt as to the necessity for a permit the appropriate State and Corps district office be contacted for the determination. Federal permits are issued by the Corps of Engineers, only after a state permit or waiver thereof has been obtained. Upon receipt of application for permit, the Corps District Office is required to issue a Public Notice describing the proposed work for comment or objection by interested parties. The normal advertising period is 30 days; however, where the applicant indicates urgency for the work the advertising period can be reduced. Normally, if no objection is received, the District Engineer is authorized to issue the permit. A pamphlet, EP 1145-2-1, 1 November 1977, entitled "U.S. Army Corps of Engineers Permit Program, a Guide for Applicants", describing the procedures for applying for a Federal permit, may be obtained free of charge from any Corps of Engineers' district office.

District Engineer
U.S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo New York 14207

District Engineer
U.S. Army Engineer District Detroit
P.O. Box 1027
Detroit, Michigan 48231

District Engineer
U.S. Army Engineer District Chicago
219 South Dearborn Street
Chicago, Illinois 60604

District Engineer
U.S. Army Engineer District St. Paul
1135 U.S. Post Office and Customhouse
St. Paul, Minnesota 55101

Information regarding the procedures for applying for a state permit should be obtained from the following state agencies:

Chief Waterway Engineer
State of Illinois
Division of Water Resource Management
201 West Monroe Street
Springfield, Illinois 26706

Chief, Division of Water
Indiana Dept. of Natural Resources
605 State Office Building
Indianapolis, Indiana 46325

Chief, Submerged Lands Unit
Division of Land Resource Programs
Michigan Department of Natural Resources
P.O. Box 30028
Lansing, Michigan 48909

Minnesota Dept. of Natural Resources
Div. of Water, Soils & Minerals
Centennial Office Building
St. Paul, Minnesota 55155

Central Permit Agent
New York State Water Resources Commission
State Campus
Albany, New York 12226

Staff Coordinator
Ohio Dept. of Natural Resources
Ohio Dept. Building, Room 815
65 South Front Street
Columbus, Ohio 43215

Chief Engineer
Pennsylvania Department of Environmental Resources
P.O. Box 1467
Harrisburg, Pennsylvania 17120

Director, Bureau of Water and Shoreland Management
Division of Environmental Protection
Wisconsin Dept. of Natural Resources
Box 450
Madison, Wisconsin 53702

DEFINE THE PROBLEM:

The factors affecting shore erosion are the orientation of the shoreline, offshore depth, and the resistance of the shoreline to wave action. An individual assessment of your situation should be described in terms of backshore form, such as low bluff or high dune, offshore slope, and the existence or lack of a beach. Review the columns under type of shore on page 7 to determine what types of shore protective structures should be employed for various situations. Construction alternatives, pros, cons and costs are shown on subsequent pages. The cost estimates given are only a guide and will vary with locality.

SELECTING A PLAN OR PROTECTION

The cost of a structure, the risk and consequence of failure, and the materials available will decide the type of structure and its construction details.

The primary decision in contending with serious shore erosion problems is a choice of (1) relocation (2) armor the base or toe of the bank (3) build beaches or (4) reduce the force of the offshore waves. Relocation requires an alternative site for the home and a house-moving company. Armor requires good foundation conditions and the availability of heavy stone or other heavy material and access. Beach building requires artificial replenishment or an area where large quantities of beach material move along the shore. Devices which retain placed sand or entrap the natural littoral drift are offshore breakwaters, groins or, in the backbeach area, vegetation.

There is no single type of permanent or temporary protection that should be used in all cases. The most suitable type for individual selection can only be determined by consideration of specific information about the area to be protected, such as surveys, soil conditions, wave climate, set up, etc. The cost of protection varies considerably. Low-cost emergency protection can be provided for about $10 per foot, while permanent protection might cost up to $500 per foot of shoreline. Because of varying conditions of the shoreline around the various lakes, it is probable that the best plan of protection would involve a wide range of designs, depending on availability of materials and the severity of erosion. A number of these alternatives are described beginning on page 8.

The availability of materials will dictate the type of structure and its cost. For example, the lack of stone within economic hauling distance would require the use of some other material.

Some materials are very good, i.e., quarried stone, pre-fabricated concrete units, interlocking steel pile and creosoted wood timbers. Some materials are not acceptable such as junk cars, old tires, thin concrete slabs, and empty septic tanks, and may be against state law. In between these extremes is a range of materials that can be used if care, discretion, and ingenuity are applied to produce a more durable structure. Materials can be used in conjunction with other materials, for instance, wire fencing and stones; or quarried stone, cloth bags and grout; or steel sheet piles and quarried stone.

The desired life of the structure also dictates its type. Obviously, an untreated timber structure should not be installed where a structure is desired to last 50 years. Conversely, a permanent rubble-mound structure would not be required if the need for protection was of an expedient nature. The durability of the structure and its ability to absorb wave energy is also a factor.

The Corps prefers and recommends that permanent protective works be built, but understands that private owners usually can't afford the large cost. This means there may have to be departures from the standard designs for permanent protective works to provide some degree of protection against erosion. This will tend to decrease the first cost of construction; however, higher maintenance cost and reduced functional life will follow. The danger here is to underdesign the work and experience total failure. Close attention to the construction and maintenance guidelines given later in this pamphlet are needed to minimize losses.

BUILDING PROTECTIVE WORKS

Timeliness is the essence of the successful construction of shore protection measures. The best time to build shore protection structures is during low-water periods. Greater construction problems exist during high lake levels when many beaches are submerged making access difficult. The lack of time precludes an in-depth study of the problem, requiring a hasty solution.

Once the general plan of protection has been determined it should be discussed with the appropriate Corps of Engineer District, Permits Branch. The permit application will require your plan, and information on any borrow or disposal sites and may require 90 days to process.

The final design of protective works can proceed once the general plan of protection has been selected. The data herein describe the general plans. The final plan should include a layout drawing, construction details, and materials specifications. A complete alignment of the structure should be established as early as possible. Take advantage of the remaining beach and tie into adjacent shore protection works if possible. Provide enough room for the specified minimum slopes if you are building a revetment. As soon as the alignment is established, quantities can be estimated for establishing equipment and materials requirements.

Access roads and borrow areas should be identified on the plan. Local contractors and local officials can provide information on sources of material and load restrictions on streets and highways. The use of heavy equipment on residential streets can result in severe damage to the pavement.

Another important consideration is the selection of the proper equipment to do the work. Utilize the contractor's experience to establish the best use of equipment and the most efficient operation.

Contracts for shore protection works delineate the responsibilities of both parties, the owner and the contractor. The contract should be based on plans and specifications and include prices for the estimated quantities of work. It is important that both parties fully understand the scope of work. You should get "bids", i.e., prices, from a number of contractors, to insure obtaining quality work at the lowest price.

CONTRACT PLANS AND SPECIFICATIONS (TYPICAL)

For your protection, contract plans and specifications* should be provided to or by your contractor. This should include some, if not all of the following:

Location of the work with respect to the highway right-of-way and the shore.

Survey control and relation of elevations to lake levels and both expected highwater conditions and low water datum (LWD).

A typical cross-section indicating dimensions, slopes, arrangement and connections.

Quantity of materials (per lineal foot, per protection unit, or per job).

Relation of the foundation treatment with respect to the existing ground. Relation of the top of the proposed protection to design high water and low water datum.

The limits of excavation and backfill as they may affect measurement and payment.

Construction details such as weep holes and pervious materials associated with them.

Location and details of construction joints, cut-off stubs and end treatment.

Connections and bracing for framing of timber or steel.

*Sample specifications are shown on page 18.

Anchorage and splicing details, particularly size, type, location, and method of connection.

Number and arrangement of cables and details of fastening members.

Pile construction, the number of piles, length of piling, driving requirements, cut-off elevations, and framing details.

The details of adjustable wire baskets (gabions) and the material to be used to fill the baskets.

Concrete specifications, materials specifications, placement instructions, quality control and description of payment items.

Start-up and completion time for the work.

ENVIRONMENTAL CONSIDERATIONS

Since installation of shore protection devices usually produces some change in the nearby shoreline environment, thorough planning and design requires consideration of the full impact of the expected changes on the ecological and aesthetic value of the area to be protected. If the possibility exists of adverse environmental or social effects resulting from construction of a shore protection device, Federal and state law requires consideration of alternatives to avoid or mitigate the effects. Possible adverse environmental effects of a shore protection device are considered in the review process discussed previously under Permit Requirements. Expected shoreline changes that might be produced by some shore protection devices are discussed with other design aspects of the devices beginning on page 8.

SAFETY CONSIDERATIONS

Common sense safety is necessary to reduce the chance of injury and possible loss of life. Some safety considerations are listed below:

Safe access and safe working conditions must be provided at all work areas. Unstable bluffs must be graded to a safe slope.

A first-aid kit should be available. Everyone should be physically qualified to perform the work required. No one should expose themselves to injury.

Protective clothing, such as safety shoes, gloves, goggles, and hard hats should be worn by persons engaged in work requiring this protection.

Construction materials should be stored in an orderly manner on a solid, level surface.

Waste materials should be removed from the work area daily.

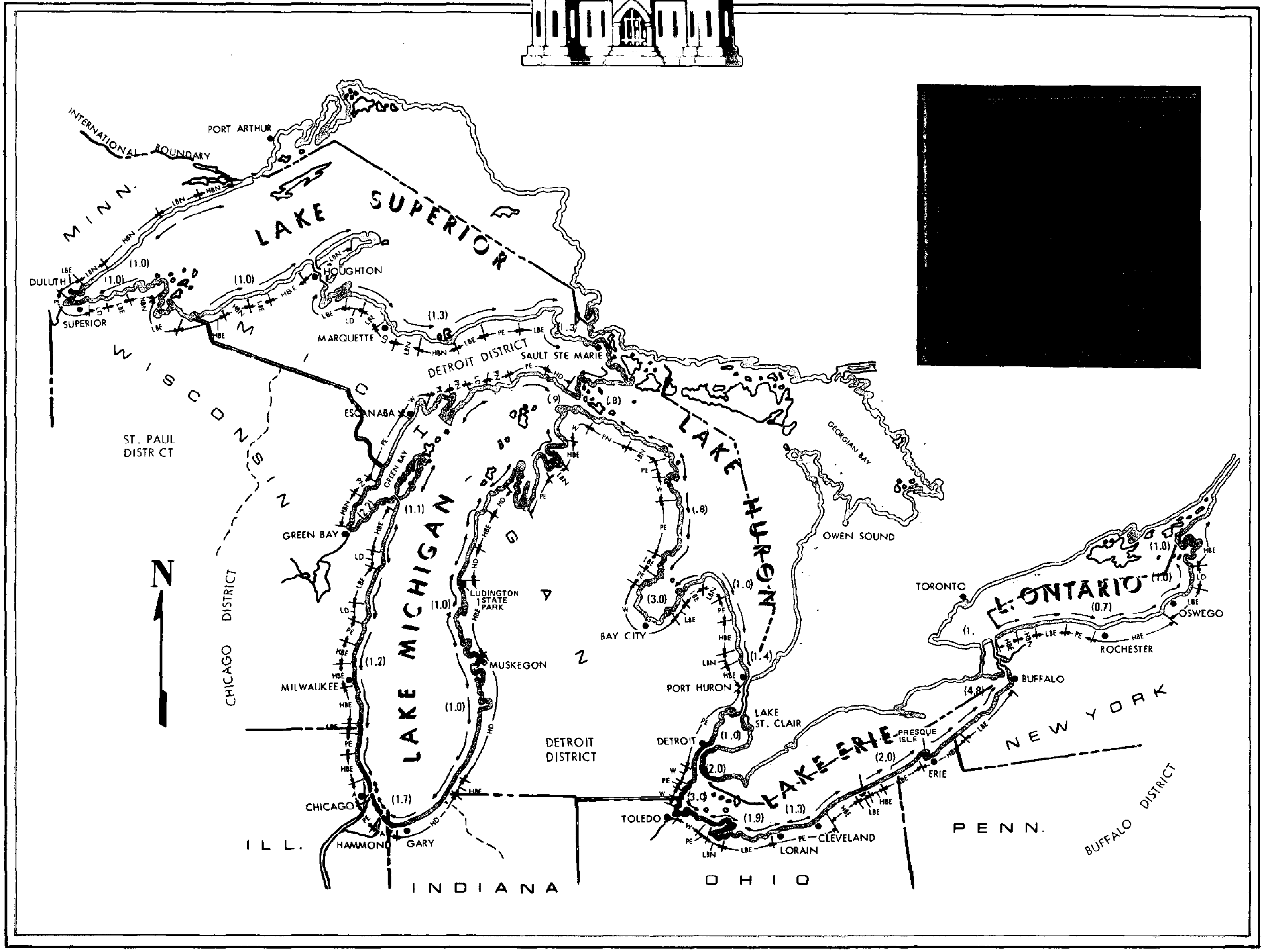
INSPECTION CONSIDERATIONS

Supervision of construction is very important. Close attention to detail is needed to assure the final design will perform as anticipated. Prior to and during actual construction make a complete review of the plan. A check list of the important items are described below.

- Start a pictorial record with pictures of existing conditions. Continue this through all stages of construction.
- Establish elevations of known points, layout line, and grade for construction.
- Note changes in the terrain that may require a change in the plan or the layout of construction.
- Check material sources for compliance with plans.
- Inspect work to insure compliance with plans.
- Record dimensions, limiting heights and depths on as-built plans.
- Maintain pictorial record throughout the life of the structure, particularly after damaging storms.

GREAT LAKES SHORELINE

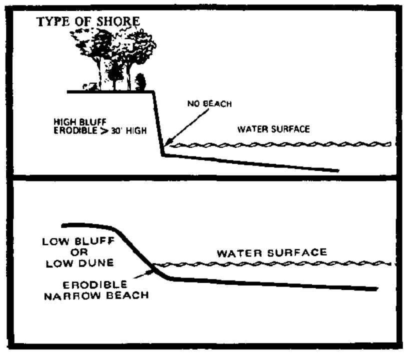
UPLAND SHORE TYPE AND DIRECTION OF NET LITTORAL TRANSPORT



A GUIDE FOR SELECTING A TYPE OF SHORE PROTECTION

Determine the shore type at the location to be protected from the map on the opposite page or from an on-site inspection. The following chart may be used as a guide in selecting suitable shore protection devices. Possible solutions to erosion control are categorized below by the function they serve; for example: bluff protection, beach accretion, and etc.

FLAT OFFSHORE SLOPES



POSSIBLE SOLUTIONS

BLUFF PROTECTION

Revetments
- Stone
- Gabion
- Bag-Grout filled

Bulkheads
- Steel pile
- Timber pile
- Timber cribs (stone filled)
- Wood pile wire mesh fence (stone filled)

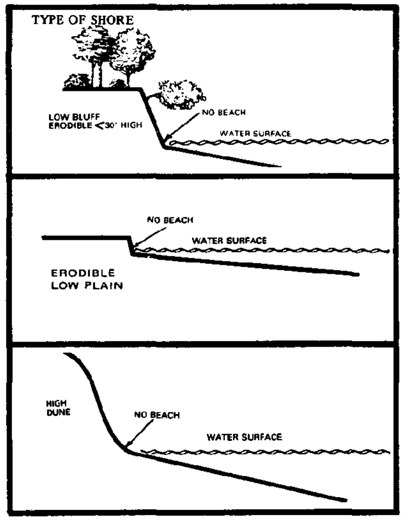
Beach Fill

BEACH ACCRETION
- Offshore breakwater
- Impermeable groin
- Vegetation

RELOCATION

BLUFF STABILIZATION
- Drainage
- Sloping

MODERATE OFFSHORE SLOPES



POSSIBLE SOLUTIONS

BLUFF PROTECTION

Revetments
- Stone
- Gabion
- Bag-Grout filled

Bulkheads
- Steel pile
- Timber pile
- Timber cribs (stone filled)
- Wood pile wire mesh fence (stone filled)

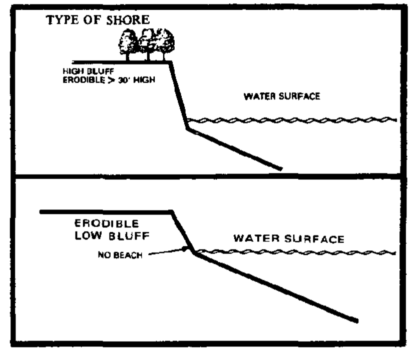
Beach Fill

BEACH ACCRETION
- Offshore breakwater
- Impermeable groin
- Vegetation

RELOCATION

BLUFF STABILIZATION
- Drainage
- Sloping

STEEP OFFSHORE SLOPES



POSSIBLE SOLUTIONS

BLUFF PROTECTION

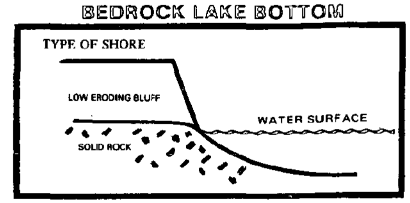
Revetments
- Stone
- Gabion
- Bag-Grout filled

Bulkheads
- Steel pile
- Timber pile
- Timber cribs (stone filled)

RELOCATION

BLUFF STABILIZATION
- Drainage
- Sloping

BEDROCK LAKE BOTTOM



POSSIBLE SOLUTIONS

BLUFF PROTECTION

Revetments
- Stone
- Gabion
- Bag-Grout filled

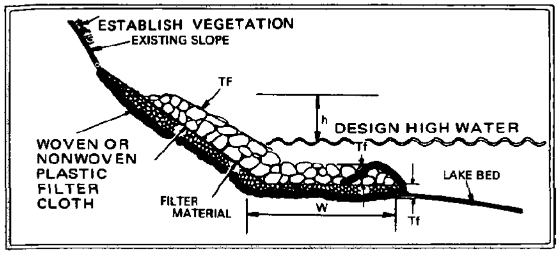
RELOCATION

CONSTRUCTION ALTERNATIVES; BLUFF

REVETMENTS

Revetments are structures placed at the toe of bluff parallel or nearly parallel to the shoreline to protect against wave action. Three examples are shown below.

STONE REVETMENT



Stone revetment is the preferred method of shore protection. It is economical and suitable for all types of erosion problems when stone is available in sufficient size and quantity. The key design considerations, are the dimensions, foundation treatment, and stone size. Construction is not complicated and no special equipment, other than a crane and trucks are needed.

NOTES:

1. Slope should be compacted and graded to 1:2 or flatter.
2. Place a gravel, small rock, filter blanket, and/or filter cloth on the prepared slope.
3. Place rock carefully with a crane; rock should be supported at three locations.
4. Insure rock sizes are well mixed. Larger and smaller rock should not be visibly segregated.

MAINTENANCE REQUIREMENTS

This structure is subject to displacement. The effectiveness of the structure will be impaired by thinning of the protective layer or settling of the structure. Restoration of the rock slope protection to the designed top elevation, equivalent thickness and reduction of voids in the facing should be accomplished when needed. The list of materials and general costs information is given in the following tabulation.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Thickness (ft)	2	4	5
Average Wt of Stone (#)	200 – 500	750 – 2000	2000 – 5000
Height of Structure (ft)	4	6	8
Toe Protection Width (ft)	2	4	5
Filter material	Cloth		
List of Materials (per ft)			
Stone (tons)	1.89	4.94	7.36
Filter (sq ft)	13	19	22
Cost $/Lin. Ft.	50	130	230

ADVANTAGES

Most effective structure for absorbing wave energy.

Flexible—not weakened by slight movements.

Natural rough surface reduces wave runup.

Lends itself to stage construction.

Easily repaired—low maintenance cost.

The preferred method of protection when rock is readily available at a low cost.

DISADVANTAGES

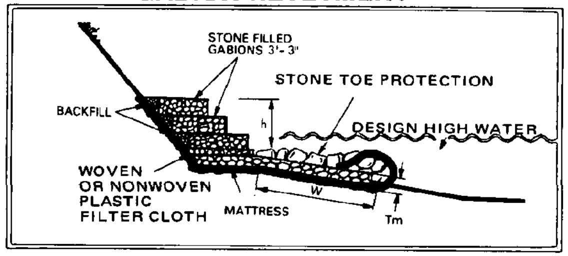
Heavy equipment required for construction.

Limits use and access to beach.

Moderately high first cost.

Difficult to construct where access is limited.

GABION REVETMENT



A gabion is a steel wire mesh basket available commercially. Revetments can be constructed from stone-filled gabions by groups of individuals without special construction equipment. Gabion structures can be built to any height required. A step design is suggested to reduce wave runup. The manufacturer's instructions should be followed closely. The structure should rest on an 18" thick gabion mattress to protect against scour. This type of construction is applicable to all shore-protection problems.

NOTES:

1. Gabions can be filled with any stone material larger than the mesh.
2. Gabion structures maintain their strength even if the foundation settles somewhat.
3. You should stagger the joints between baskets the same way you stagger the joints between courses in a brick wall to make a stronger structure.
4. You would be wise to anchor the lakeward end of the mattress with large stone or anchor screws.
5. Your mattress should extend out as far from the toe as one and one-half times the design depth.

MAINTENANCE

The life of gabion protection depends on the durability of the wire. Replace broken wires with galvanized or plastic-coated wire. The baskets occasionally are moved during severe storms, but can often be replaced after the storm. Such movement indicates foundation failure or scour at the toe. Repair all storm damage as quickly as possible.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (ft.)	5	7	9
Apron length (ft.)	2	5	7
Filter material	Cloth		
Materials (per ft.)			
Gabions (#)	1	3	4
Gabions—Stone filled (yd^3)	0.2	0.7	0.9
Gabion type mattress (yd^3)	0.2	0.4	0.7
Cost $/Lin. Ft.	40	90	120

ADVANTAGES

No special construction equipment required, rated best 'do-it-yourself' type of protection.

Flexible, easily repaired after storm damage.

Low first cost, if do-it-yourself project.

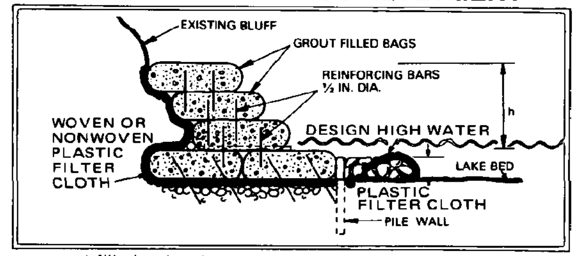
DISADVANTAGES

Subject to rusting and deterioration unless wire baskets are plastic coated.

Limits use and access to beach.

Moderate maintenance costs.

GROUT FILLED BAGS REVETMENT



Large grout-filled nylon bags (20' x 5' x 1.6") may be used to protect eroding shorelines. This type of structure is adaptable to all types of slopes. Bags should be placed parallel to the shore with reinforcing bars installed both vertically and horizontally as shown in the section above. This type of structure may be applicable where access is limited and rock is not readily available. No special material is needed other than the bags and construction is not complicated. A grout pump is required to fill the bags. Prices in the table below were computed with the assumption that ready-mix grout will be used but a concrete mixer could be substituted at the site.

MAINTENANCE REQUIREMENTS

Remedial work on this type of structure is not easily accomplished. Special attention should be given to toe protection. Uneven settlement or undermining might cause fracture or collapse. If excessive scour causes toe stone to settle, more material should be added. This type of structure is readily adaptable to add-on construction. Additional structure height can be easily accomplished if necessary.

Description	Design depth of water 50' offshore (ft.)		
	3 – 5	5 – 6	7 – 8
Dimensions			
Height of Structure (ft)	6.4	8.0	11.2
(Bags)	(5)	(6)	(8)
List of Materials (per ft.)			
Grout (Yds.^{3})	1.5	1.8	2.4
Reinforcing bars (lbs.)	10	12	16
Filter Cloth (sq. ft.)	18	21	26
Cost $/Lin. Ft.	135	160	215

ADVANTAGES

Moderate first cost.

Adaptable to stage construction.

DISADVANTAGES

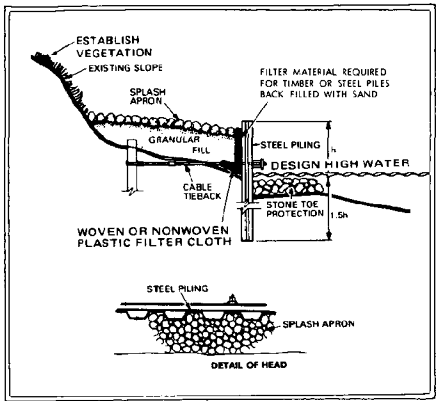
More subject to catastrophic failure if the toe is undermined.

PROTECTION

BULKHEADS OR SEAWALLS

Bulkheads are structures placed at the toe of bluff parallel or nearly parallel to the shoreline with the primary purpose of preventing the sliding of land or slope failure. The secondary purpose is to provide protection against wave action. Examples of several different types of bulkheads are shown below.

STEEL BULKHEAD



A steel bulkhead serves to armor the bank. The face must be designed to absorb all wave energy. Severe scour occurs at the bulkhead line. The sheeting depends upon penetration and tie backs for its stability. The structural design of sheet piling is highly specialized and not subject to standard plans. For this reason the service of a qualified engineer is essential. Key design considerations are foundation conditions, penetration of the piling, height and alignment, and scour protection. Sufficient access must be available for pile-driving equipment.

Piles shall be carefully located as shown on the drawings and driven in a plumb position, each pile interlocked with adjoining piles for its entire length, so as to form a continuous diaphragm, throughout the length of each run of wall. The Contractor shall drive all piles as true to lines as practicable and shall provide suitable temporary wales or guide structures to insure that the piles are driven in correct alignment.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (h)	5	8	10
Piling length	13	20	25
Toe protection apron length	2 x 2	4 x 4	5 x 6
List of Materials (per ft.)			
Steel Piling (s.f.)	13	20	25
Waler (ft.)	1	1	1
Fill material (yds.)	.9	2.0	3.0
Toe Protection (yds.)	.15	.60	.95
Cost $/Lin. Ft.	290	460	580

ADVANTAGES

Provides substantial protection.

Maintains shoreline in fixed position.

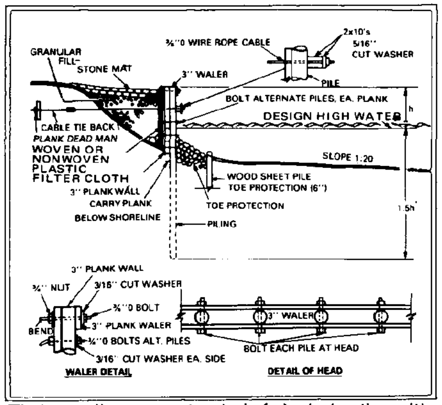
Low maintenance cost.

Materials are readily available.

DISADVANTAGES

Structural integrity depends upon adequate toe protection.

TIMBER WALL BULKHEAD



Timber walls are constructed of plank sheeting with round piles. They consist of two rows of 3-inch plank sheeting and a row of round piling with heavy horizontal walls between the planks and the piling. They must be tied back to anchor piling. The most common cause of failure of sea walls is undermining of material from the bottom of the toe of the structure, resulting in inadequate penetration of piling. The pressure of the soil and water on the back side can then tip the structure. The tie-backs provide additional strength to resist this force. Timber bulkheads also require positive toe protection.

The piling and sheeting are driven with the aid of a jet from a small pump. The use of this design is controlled by subsurface foundation conditions. It is suitable for sand or sand and gravel shores where the sand deposit is 12-15 feet below the lake bottom. Wooden structures must be securely fastened together with bolts.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (ft.)	5	8	10
Diameter of Piles (in.)	6	8	10
Pile length (ft.)	13	20	25
Wall plank thickness (in.)	3	3	3
Toe protection wt (lbs.)	70	140	200
List of Materials (per ft.)			
Piling	5.3	8.0	9.3
Waler	1	1	1
Wall Plank (s.f.)	6	9	11
Filter Blanket (s.f.)	9	12	16
Toe Stone (c.y.)	.3	.7	.95
Fill Material (c.Y	.9	2.0	3.0
Costs $/Lin. Ft.	70	95	150

Vertical walls induce severe scour at their base.

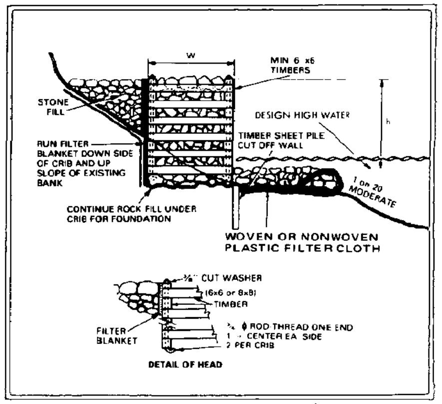
High first cost.

Pile driving requires special skill and heavy construction equipment.

Complex engineering design problem.

Limits access and use of beach.

TIMBER CRIB BULKHEAD



Heavy duty timber cribs can be used for bulkheads. Timber cribs use log-headers and stretchers. Headers must be long enough to integrate a stable mass of backfill. Dimension lumber can also be used. Backfill for cribs must be self-draining and secure against erosion. The base of the toe must be protected from scour.

NOTES:

Notch logs to reduce spacings between members. Fill cribs with field stone up to 50 pounds. Provide a gravel bed foundation. Backfill area between bluff and crib with bank run gravel.

Place a storm splash apron on backfill.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (ft.)	5	7	Not Recom-mended
Width (ft.)	4	5	
Cut off wall (ft.)	6	9	
Cap stone (lbs.)	100	200	
Stone fill (lbs.)	10 – 50	10 – 50	
List of Materials (per ft.)			
Timber cribbing 6"x 6")	20	24	
Rock fill (cu. yds.)	.9	1.0	
Capstone (cu. yds.)	.2	.2	
Sheeting (sq. ft.)	6	9	
Anchor rods (ft.)	6' – 0"	8' – 0"	
Cost $/Lin. Ft.	70	85	

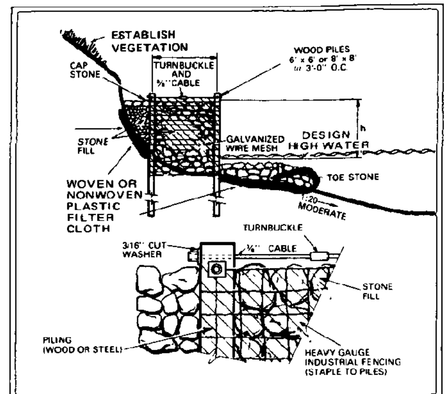
ADVANTAGES

Lends itself to protecting short reaches.

Can be constructed of materials that are readily available.

Structure is easily repaired.

WIRE FENCE BULKHEAD



Fence-type structures can be constructed of timber, or metal posts or piling, and wire fence or lumber. The fences can be built of single, double, or triple rows. Posts should be driven below possible scour. Woven-wire fabric is preferred to welded wire fabric.

This type of protection consists of fence, filled with stone, and anchored to the embankment. The fence is used to hold small stones in place that would be displaced by wave action.

The more important design considerations include: the piling length, the size of the wire fence fabric, the design of the compartment to hold the stone, and the method of anchoring the stone-filled fence to the embankment.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (ft.)	5	6	9
Length-wood piles (ft.)	13	15	23
Diameter wood piles (in.)	8	8	10
Stone fill (lbs.)	30 – 50	30 – 50	30 – 50
Cap stone (lbs.)	100	200	300
List of Materials (per ft.)			
Piling (lin. ft.)	17	20	30
Stone fill (cu. yd.)	.53	.60	.90
Cap stone (cu. yd.)	.17	.17	.17
Fencing (sq. ft.)	27	30	42
Cable (ft.)	2.3	2.3	2.3
Toe Rock (cu. Yd.)	.40	.46	.53
Costs $/Lin. Ft.	110	125	180

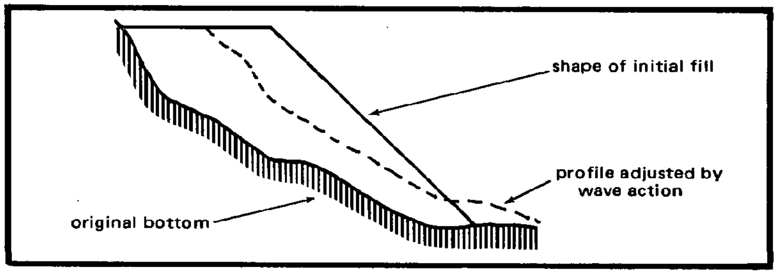
DISADVANTAGES

Structural integrity depends upon adequate toe protection. Vertical walls induce severe scour at their base.

Limits use and access to beach.

BEACH FILL OR ARTIFICIAL NOURISHMENT

A beach fill artificially replaces material lost naturally to littoral processes.



Depending on the beach width and slope, a beach fill affords some storm protection for the land area behind the beach by dissipating wave energy as the waves break on the beach. Artificially placing suitable material (predominantly medium sand) on the shore to restore or create a protective beach directly replaces the littoral materials that are removed and not replaced by natural processes without inducing damage to shore areas beyond the project area. When sand is placed on a beach, waves sort the surface layer of the fill moving the finer particles lakeward while the coarser particles remain near the point where the waves break. This causes an adjustment of the beach fill profile as shown in the above figure. The adjustment continues until the grain sizes on the beach are compatible with the normal wave climate.

Planning for a protective beach by artificial nourishment requires: knowledge of the littoral transport rate and direction at the site; information on the grain sizes of the beach material at the site, as well as that of the material to be placed on the beach; and determination of the shape of the initial fill and how the beach profile will adjust when subjected to wave action. Although beach fill may often be the most environmentally acceptable solution to shore erosion control, the preceding requirements make designing a protective beach difficult.

MAINTENANCE REQUIREMENTS

Beach fill often needs to be periodically nourished because of littoral transport. It may be difficult to find economic sources of borrow material with grain sizes similar to the existing or native beach material. However, if the borrow material is much finer than the native material, large losses generally occur soon after placement of the material.

COST

The cost of a beach fill varies with amount of initial fill, frequency and amount of nourishment required, and transport methods and distances. Initial costs may be low if an adequate borrow source is nearby.

ADVANTAGES

Recreational area is provided if beach is of suitable dimensions.

Beach nourishment benefits rather than endangers downdrift area.

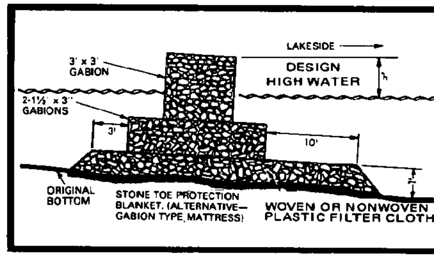
DISADVANTAGES

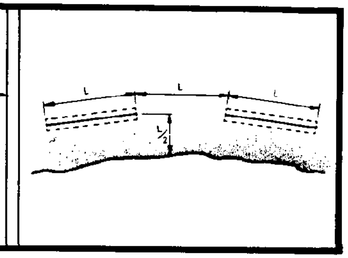
May be difficult to maintain in areas of rapid erosion or where no previous beach existed.

GABION BREAKWATER

OFFSHORE BREAKWATER

The breakwater is placed offshore from and usually parallel to the shoreline to protect a shore area from waves.





Offshore breakwaters are an acceptable method of shore protection for flat or moderate offshore slopes. The design wave is based on water depth 50 feet lakeward of the structure.

Offshore breakwaters can be constructed of any material capable of withstanding the wave energies impinging upon them, including stone, gabions, steel, wood, and concrete shapes. A toe protection blanket is essential. Offshore breakwaters may be low structures to allow passage of wave energy or they can be high structures to completely block waves. They should be built in shallow water nearshore for reasons of economy. They can be continuous for long distances or segmented with passages between them to allow exchange of water.

Caution: Offshore breakwaters interfere with shore processes; their use demands extreme caution to preclude major downdrift erosion. Consider them only in areas of substantial sand movement. Make them low so they will be overtopped by waves during storms. Offshore breakwaters are difficult and expensive to maintain.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Height (ft.)	1.5	2.0	Not Recom-mended
Apron length (ft.)	10.0	10.0	
List of Materials			
Gabions—Stone filled (yd^3)	0.7	0.7	
Stone toe protection (yd^3)			
Cost $/Lin. Ft.	100	120	

ADVANTAGES

Beneficial effect can extend over a considerable length of shoreline.

Maintains or enhances recreational value of a beach.

The structure is not subject to flanking—it can be built in separate reaches.

Gabions can be constructed on shore and transported to site by ordinary earth-moving equipment.

Tends to build a natural beach between the breakwater and the shore.

DISADVANTAGES

May modify beach line and cause erosion in downdrift areas.

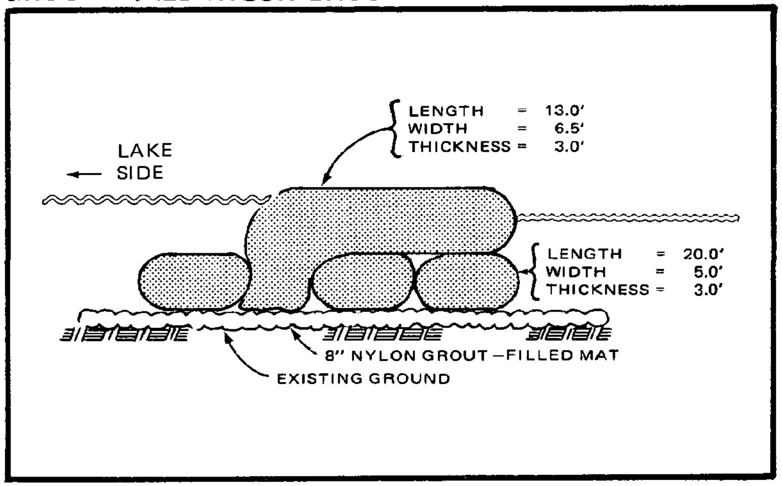
Structure is subject to foundation and scour failures; floating plant and heavy equipment may be required for construction.

Gabions may be damaged by floating ice or logs.

Extremely difficult to repair.

Offshore breakwaters also function as wave height reduction or attenuation devices on their landward side. An alternative design to the gabion breakwater on the opposite page is shown below. Offshore breakwaters

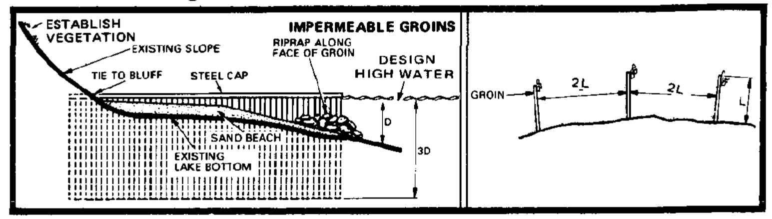
GROUT FILLED NYLON BAGS



function by reducing the wave energy which strikes the shore and by creating a quiet zone where sand is trapped. The height, length and distance offshore at the breakwater will control the size of the beach which develops behind the structure.

IMPERMEABLE GROIN

Groins are usually constructed perpendicular to the shoreline and extend into the water far enough to effectively trap and retain littoral drift to build a beach or minimize erosion of an existing beach.



Protection of the shoreline by groins assumes sand is available and is moving along the shoreline. Groins can have the undesirable effect of damaging downdrift shores. The layout of groins is very important. Groins should be kept *low, only one foot above the expected high water, and short, terminating at the 3-*foot depth. Groins must be protected from flanking by tying them well into the bank. The maximum length of groins should not exceed 100 feet. If possible groins should be artificially nourished by placing sand on the updrift side of each groin.

Caution: Groins are shore protection structures that interfere with shore processes and entrap beach materials. Their use demands extreme caution to preclude major downdrift erosion. Consider them only in areas of substantial sand movement. Make them low so they will be overtopped by waves during storms. Groins should be constructed in stages, starting at the extreme downdrift end of the area to be protected. Study the effects of the single groin carefully before completing the layout of the groin field.

Description	Design depth of water 50' offshore (ft.)		
	3 – 4	5 – 6	7 – 8
Dimensions			
Steel Piling (length) (ft.)	115	65	Not
Steel Piling (wetted length) (ft.)	100	50	Recom –
Depth (ft.)	15	15	mended
Groin Spacing (ft.)	200	100	
List of Materials (per groin)			
Sheet Piling (tons)	27	16	
Timber Walers (tons)	3	2	
Stone Filter Blanket (tons)	90	90	
Stone Rip rap (tons)	140	140	
Cost $/Lin. Ft.	200	215	

ADVANTAGES

Resulting beach protects upland areas and provides recreational benefit.

Moderate first cost and low maintenance cost.

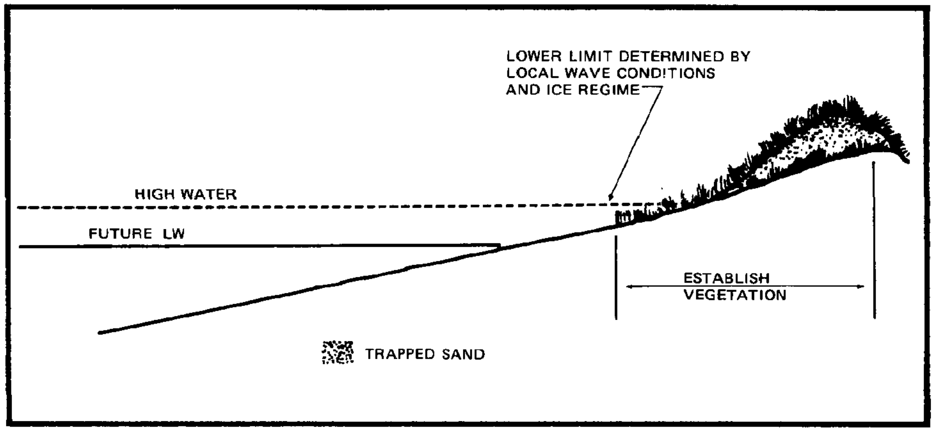
DISADVANTAGES

Extremely complex coastal engineering design problem. Qualified coastal engineering services are essential. Groins rarely function strictly as intended.

Areas downdrift will probably experience erosion.

Unsuitable in areas of low littoral drift. (Sand movement)

Subject to flanking; must be securely tied into bluff.



VEGETATION

Sandy beach areas lose sand inland through wind transport. Much of the sand transported from the beach area can be trapped by planting and/or fertilizing appropriate vegetation in the area above the wave activity. As shown in the accompanying figure, the vegetation actually helps form a sand dune system and when storms occur, particularly during periods of high water level, this reservoir of sand serves to absorb wave energy and slows shore erosion.

Many factors affect the efficiency of vegetation to trap sand. The availability and volume of sand being transported from the beach, and a sand transport season that coincides with the vegetative growth season, are of prime importance in the Great Lakes area. When high wave action occurs, particularly during high lake levels, the vegetation may be destroyed and the trapped sand redistributed to the beach. Therefore, the shorefront owner should be aware that the life span of a portion of the planted or natural vegetation may be as short as the period between major storm wave attacks and periodic maintenance of the vegetation may be required.

Caution: Dune stabilizing vegetation is designed to develop the dry back beach area by trapping wind-blown beach material. Consider them only in areas of substantial sand supply. Direct wave attack will eventually destroy the protective dunes.

COST

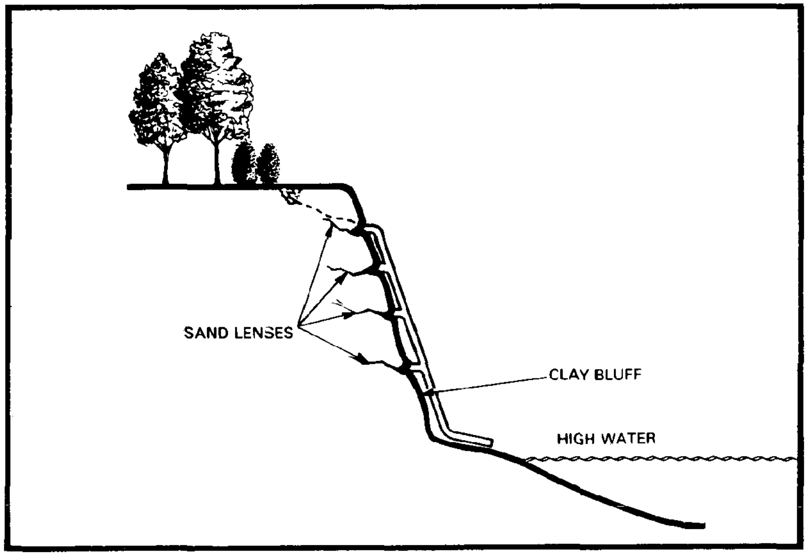
The cost of vegetative plantings could be as low as $10 per foot of shore front depending on plant species availability and area to be covered.

Information about plants and sources, site preparation, transplanting and maintenance procedures is available from your local USDA Soil Conservation Service representative.

Also, the Great Lakes Basin Commission, in cooperation with other Federal and state agencies has prepared a publication entitled "The Role of Vegetation In Shoreline Management" as a guide for Great Lakes shoreline property owners.

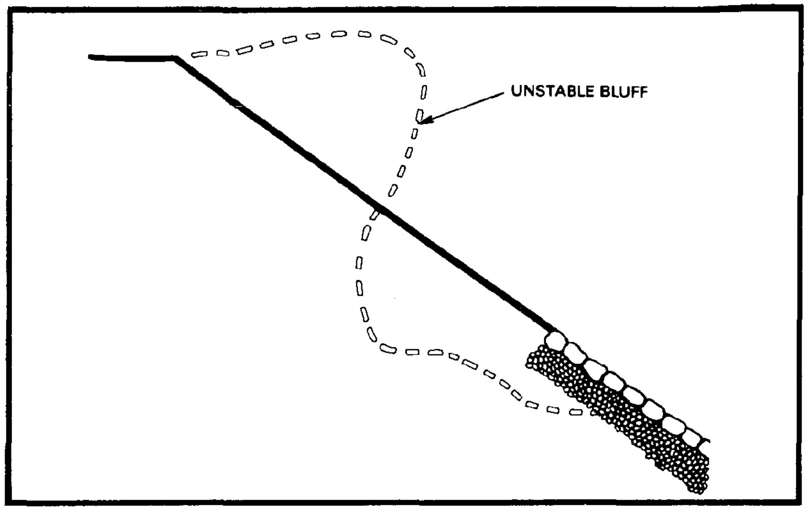
BLUFF SEEPAGE PROBLEMS

Bluff seepage problems are common for the clay bluff shoreline. Drainage should be provided where sloughing of banks caused by water seepage occurs through the upper relatively pervious strata to the impervious hardpan which underlies it. The saturated upper layer is unstable and sloughs off in large sections after which it is easily carried away by wave action. Wherever the natural slope of the ground surface behind the top of the bluff is toward the lake, drains paralleling the top of the bluff should be installed to collect the surface run-off. An open joint tile drain laid in a trench about 2 feet deep located 10 feet back from the top of the bluff and backfilled with crushed stone or gravel can be provided for this purpose. Paved gutters or tile drains down the face of the slope are necessary to carry the water which is collected by this drain to the lake. A tile drain along the foot of the slope just above the impervious strata with branches leading to the lake can be added to collect the seepage at this point and prevent softening of the toe of the slope.



CAUTION: This will not eliminate erosion due to wave action.

Frequently the combination of bluff seepage and wave erosion is responsible for continual bluff loss. In this case it will be necessary to protect the toe of the bluff in addition to the drainage work.



An alternative approach to the problem of steep and unstable slopes is excavation and slope protection. This plan consists of grading and landscaping the bluffs to a stable slope and the armoring of the toe of the slope as shown above. Revetments, beach accretion devices and bulkheads can be used for protecting the toe of the slope. The general cost of bluff treatment including excavation fill and seeding is $25 per foot. This cost does not include mobilization and demobilization costs for the required construction equipment.

The contractor should carefully plan his work to minimize the erosion damages during construction. The work should be accomplished by reach. Toe protection for the graded slope should be provided as soon as possible after the excavation and filling operations are completed.

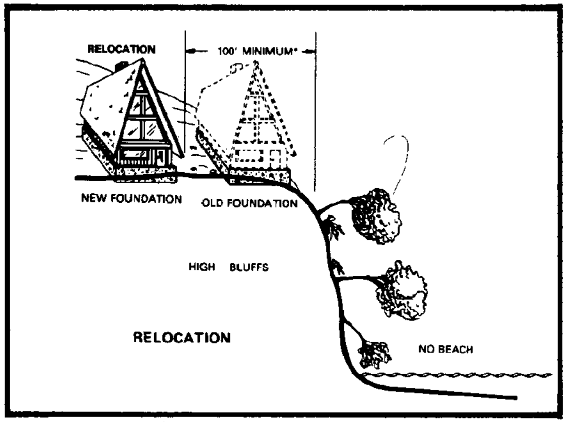
Bulkheads are considered as a method for armoring an erodible bluff. Bulkheads can also be used for retaining an unstable slope from sliding. The design of retaining walls is beyond the scope of this pamphlet.

CAUTION:
Unstable bluffs shall be graded to a safe slope before anyone is allowed on the beach.

NOTE:
Additional information on bluff stabilization may be found in "Harmony With the Lake: Guide to Bluff Stabilization", distributed by the Illinois Department of Transportation, Room 1010, Marina City Office Building, 300 North State Street, Chicago, Illinois 60610.

RELOCATION

Relocation is an alternative that cannot be overemphasized. Erosion is a natural geologic process that is extremely difficult to stop. The alternatives to build shore protection or to relocate must be weighed against the consequence of failure. Depending on the type of structure you might consider, it may cost the same to relocate as it would to build shore protection. Should a protective structure fail, then your investment in the structure is lost and your home or cottage is still in danger.



This alternative provides for the permanent relocation of homes subject to destruction by erosion-induced foundation failure. Relocation is accomplished by home movers. The important planning consideration is the rate of erosion. Key design considerations are the condition of the home, foundation and utilities, access and obstructions, length of move, new foundation and utilities.

NOTE:
Move 100' minimum or comply with state set back requirements.

Home moving is a highly specialized activity requiring a qualified home mover.

This alternative may be more economical than the installation and maintenance of shore protection.

RECESSION RATES
Long-term quantitative data on the rate of recession of a bluff or dune may be obtained from historic records of the area or the state. Early surveys and plat maps may contain survey points and a plot of the bluff line and shoreline as of the date of the survey. Utilizing these existing data, a new topographic map can be prepared showing the historic location of the bluff and shoreline and the present location. The distance between the old and existing location documents the amount of bluff or dune recession in the period of record.

The average cost of moving a typical home is about $10,000, excluding the cost of land. This cost includes house moving ($4,500), new foundation ($4,500), and utilities and service ($1,000). The cost of a new lot varies considerably depending on location.

ADVANTAGES

It is permanent. In the long run it may be the best method of protection.

Adaptable to short reaches of shore line.

Can be accomplished by the individual through contract with a house mover.

DISADVANTAGES

Special skills and equipment required.

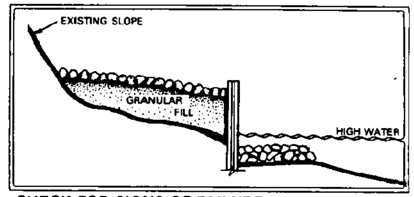
Area must be available for relocation of the house.

Does not stop erosion.

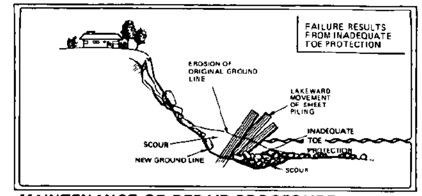
CONSTRUCTION AND

The following guidelines must be followed for any shore protection works built on the Great Lakes. If they are not followed the structure will inevitably fail after construction. Shore protection devices require varying degrees of maintenance depending on the type of structure and exposure to severe wave action. Establish familiarity with the symptoms of failure and the action that should be taken to maintain the structure. Construction rules and

RULE 1
Provide adequate protection for the toe of the structure so that it will not be undermined

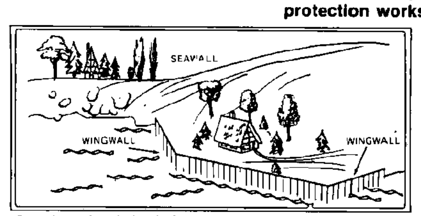


CHECK FOR SIGNS OF FAILURE
Most failures of shore protection works result from "toe failure", or erosion under the lowest part of the structure. Failure of the bulkhead can be prevented with adequate toe protection. Toe protection must be substantial enough to prevent the original ground under it from washing through the toe protection blanket, and extend far enough lakeward of the structure to prevent undermining. Check for signs of failure such as lakeward movement of the wall, erosion behind or at the toe, or at the end of the structure.

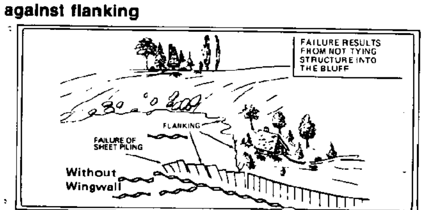


MAINTENANCE OR REPAIR PROCEDURE
Re-establish support by underpinning, tiebacks, systems of anchor piling, walers and tie rod. Place larger stone or rock-filled mattress at toe of structure to prevent scour. Backfill where necessary.

RULE 2
Secure both ends of the shore protection works against flanking

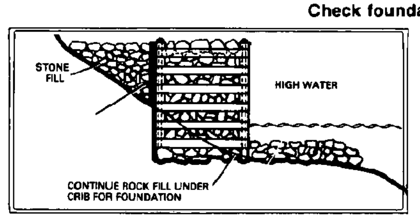


CHECK FOR SIGNS OF FAILURE
Erosion will continue adjacent to your works. If an existing structure has been flanked, such as the one shown to the right, correct it by placing additional material at the ends and tying your works directly into the bluff. Check for signs of failure such as lakeward movement of the ends and erosion at the end of the structure. The illustration to the right shows the result of not constructing wingwalls and tying the ends of the structure into the bluff.

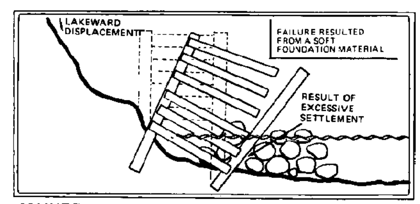


MAINTENANCE OR REPAIR PROCEDURE
Place additional material at the ends and tie structure directly back into the bluff.

RULE 3
Check foundation conditions



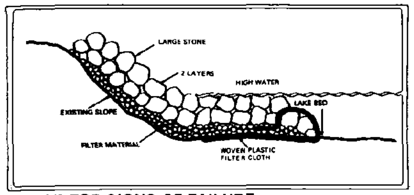
CHECK FOR SIGNS OF FAILURE
Soft foundation material may result in excessive settlement of the structure. Soft underlayers may allow all or part of structure to slide. Check for settlement, and excessive displacement. Hydrostatic pressure due to groundwater seepage may cause lakeward movement of some types of impermeable walls.

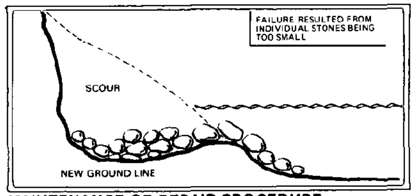


MAINTENANCE OR REPAIR PROCEDURE
Re-establish support by constructing underpinning, foundation protection and backfilling. If the structure was impermeable such as a steel wall add or reopen weep holes.

maintenance requirements are described below. Constant vigilance of all structures is necessary. Inspect your structure after every storm. Repair it immediately if it shows any sign of damage. Except for the alternative of relocation, the various structures shown below are all subject to failure if not built in accordance with construction guidelines. Once built, they must be maintained in accordance with maintenance guidelines.

RULE 4
Use material that is heavy and dense enough that waves will not move individual pieces of the protection

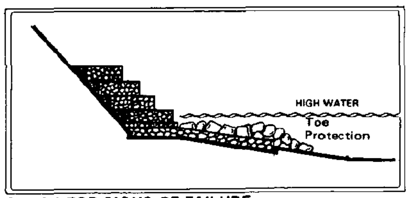


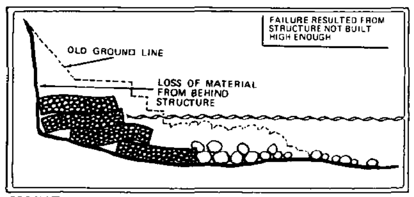


CHECK FOR SIGNS OF FAILURE
A cause of common failure is to use undersized material; waves have tremendous power and can move a lot of material in a short time. Small stones, or pieces of concrete, will be moved around and carried away by small waves. Larger waves will do it even faster. The bank revetment to the right was constructed of undersized stone that was carried down the slope by large waves. Excessive settlement, increase in voids, loss of filter material, erosion behind or at the end of the structure can result due to the use of small stone layer. Filter material may be required between underlying ground and the prospective material.

MAINTENANCE OR REPAIR PROCEDURE
Place additional stone at toe, restore to original elevation, location and thickness, reduce excessive void ratio, back fill behind structure; extensive upgrading in size of material may be required.

RULE 5
Build revetment high enough that waves cannot overtop it (spray overtopping is all right, but not "green water")

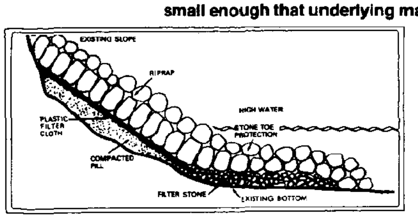


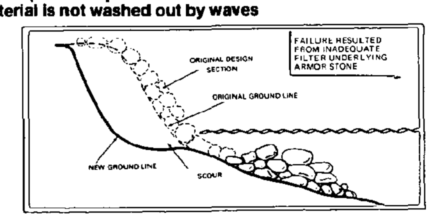


CHECK FOR SIGNS OF FAILURE
Many failures have happened because the structure was not built high enough and erosion could then continue behind the structure as if it were not there. Check for broken wire, excessive movement, and erosion behind or at ends of structure.

MAINTENANCE OR REPAIR PROCEDURE
Restore to higher elevation, back fill behind structure, add filter cloth, and splash apron.

RULE 6
Make sure that voids between individual pieces of protection material are small enough that underlying material is not washed out by waves

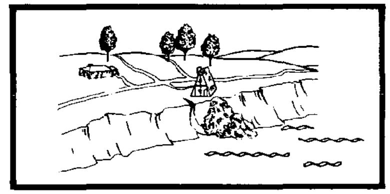




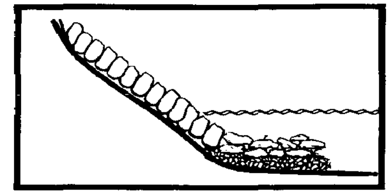
CHECK FOR SIGNS OF FAILURE
A filter material such as plastic filter cloth must be placed on a highly erodible embankment to prevent the fine material from washing through the voids in the structure. The protection material must be thick enough to make a long passage for dissipation of wave energy prior to reaching the underlying materials. In the case to the right plastic filter cloth was not included. As a result fine bluff material was washed out by waves.

MAINTENANCE OR REPAIR PROCEDURE
Rebuild to original elevation, use at least two layers of stone; use a stone filter or plastic filter cloth; fill behind structure.

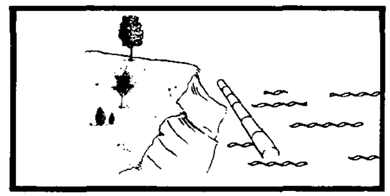
Each of these IMPROPER SOLUTIONS violates two or more construction guidelines. Can you tell which construction guidelines each of these examples violates and how the structures will fail? Answers are provided under each illustration.



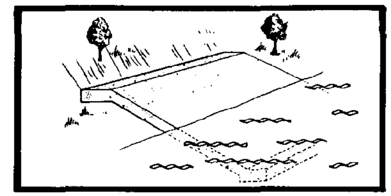
VIOLATES RULES 1, 2, 4 and 6



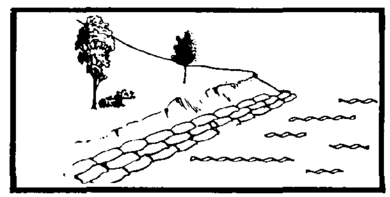
VIOLATES RULES 1, 4 and 6



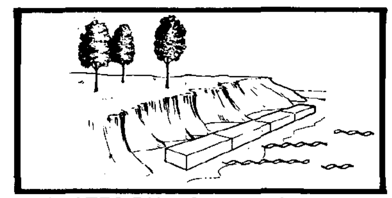
VIOLATES RULES 1, 2, 4, 5 and 6



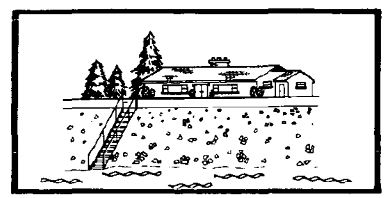
VIOLATES RULES 1 and 2



VIOLATES RULES 1, 2, 4 and 5



VIOLATES RULES 1, 2 and 5



VIOLATES RULES 1 and 4

A number of general designs for shore protection works have been presented. These plans should be adapted to the site by a qualified engineer. Please note we have arranged the designs by function: bank protection, beach accretion, wave height reduction, and bluff stabilization. Since this pamphlet is rather general it may not be applicable to unusual problems which may require a different solution.

After selection of a general plan of protection from the information given in this pamphlet, the next step in planning is concerned with the extent of the works. Particular reference to dimensions of the structure, anticipated alignment, and analysis of foundation conditions will be required.

Determination of the design wave height for a given location is critical to the design of any coastal structure subject to wave attack. The wave height is in part regulated by water depths over which the wave is passing. The design wave height is equal to 3/4 the depth of water 50 feet lakeward of the water's edge. The structures described in this pamphlet are located in very shallow water. As a result they are designed for relatively small waves.

Information on the height of the structure above the design water surface and its design specifications are given as a function of the anticipated offshore depth. (The specifications were developed based on wave heights for the various design water depths 50 feet offshore of the proposed structure which are shown so you do not have to actually determine the wave height.) This offshore design depth is made up of three components: The actual measured depth from existing lake level; the difference between the probable maximum lake elevation and the existing lake elevation; and an appropriate storm set-up value.

Upon determining the measured Depth 50 feet offshore the elevation of the lake surface in relation to sea level or low water datum must be determined. This can be done by contacting the Corps District Office in your area.

The District Offices can tell you the approximate elevation of the lake surface at the time you measured the depth 50 feet offshore. Then this can be related to the expected forecasted increase in level. The Great Lakes shoreline map on page 6 shows values of storm set-up for various points on the Great Lakes. Local variations of storm setup can be significant, particularly at the heads of bays. The determination of the design depth for a typical situation is illustrated in the diagram on the right.

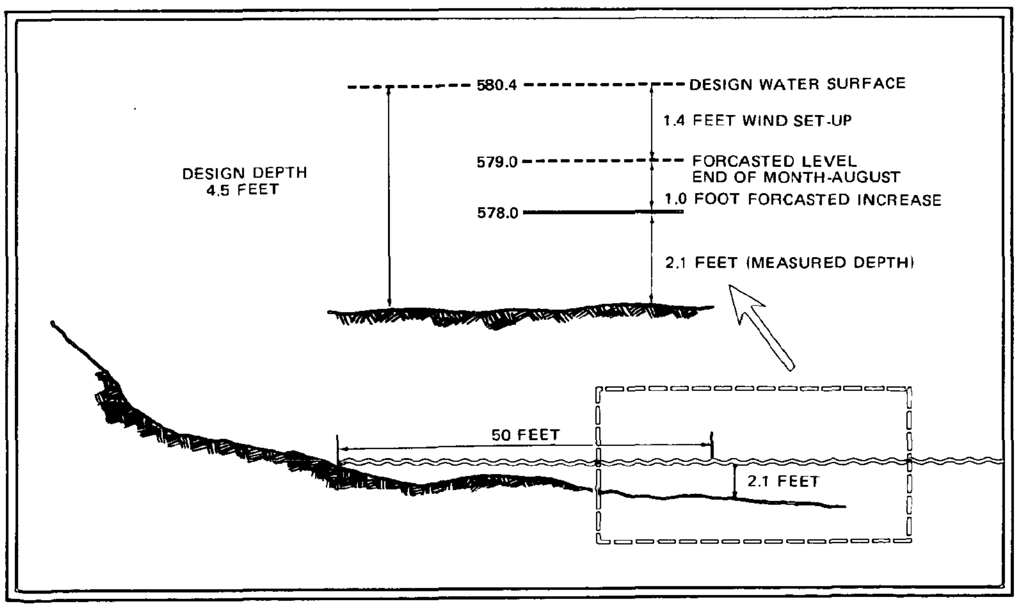
EXAMPLE OF DETERMINING DESIGN DEPTH

The measured depth 50 feet offshore near Port Huron, Michigan is 2.1 feet. Information obtained from Detroit District indicates the lake level on Lake Huron at the time you measured the depth was 578.0 feet above mean sea level. From the table on page 3 the forecasted level for the end of August can be found and is 579. From the map on page 6, the approximate wind set-up value for Lake Huron near Port Huron is found and equals 1.4 feet.

Measured Depth 50 feet offshore	= 2.1 feet
Expected increase in lake levels (579.0 - 578.0)	= 1.0 feet
Storm setup value	= 1.4 feet
Design Depth	= 4.5 feet

The general design of shore protection works and list of materials for various design depths were given in the typical general designs illustrated on pages 8 to 14. These plans show the dimensions and list of materials from a full range of offshore depths and a table of materials that can be used for the elements of shore protection structures.

Structures should also be designed and constructed in stages so that the first stage will become an integral part of more permanent protection. There is always the possibility that the works you decide to build will not function as you had intended. Supplemental construction would then become necessary. The initial works should be designed for the possibility of adding on, so that they can be incorporated into more permanent works.



Protecting the lower portion of the structure is extremely important. Toe protection should be provided to insure the integrity of the structure. This protection should extend below anticipated scour or to bedrock. This can be accomplished by protecting erodible foundation material with heavy stone.

The ends of the structure deserve careful considerations. If possible, structures should terminate at other protective works. Since this is not possible in many locations, the protective works must be returned securely into the bluff or bank. Extra materials are needed to tie into the bank.

Foundation design is another important consideration. If bulkheads are considered, subsurface investigations are needed to insure it is possible to drive the piling and to determine location of slippage planes. On the other hand, the lake bed materials may not have sufficient strength to support the protective works. A filter blanket consisting of small stones or filter cloth is needed for structures to prevent loss of fine material such as sand from beneath the structure.

The next step is the final design and layout of the protective elements. This is beyond the scope of this pamphlet and we again recommend you obtain the services of a qualified engineer; especially where the cost of the features exceed $100 per foot.

Sample government specifications covering the work illustrated in this pamphlet are provided below to assist in preparing contract plans and specifications should a contractor's services be required.

SITE WORK

This work consists of performing all excavation and backfilling. All work shall be conducted in a manner to prevent damage to the structures which are to remain and to maintain or improve the aesthetics and ecology of the site.

STONE PROTECTION

The work required consists of furnishing and placing stone as indicated on the drawings and herein. Surplus material other than stone shall be placed against the toe stone, as directed. All stone required shall be produced from quarries approved by the owner.

FOUNDATION PREPARATION

Areas on which cover stones and toe stones are to be placed shall be trimmed and dressed as needed to provide stable bedding and so that the stones may be placed within the allowable tolerances from the neat lines. Where cover stone areas are below the required depth, they shall be brought to grade by filling with core stone. To the extent practicable, the larger sizes of core stone shall be placed in the upper surface of the core stone.

LIMITING DIMENSIONS

Cover stone and toe stone shall be in pieces generally compact in shape and as nearly cubical as possible with the least dimension of any stone being not less than one-third its greatest dimension.

Stone shall consist of a well-graded mixture of sizes that will form a compact mass in place. The mixture shall be well-graded within the limits of maximum and minimum as specified on the drawings. Where space does not permit the inclusion of the larger sizes of stone, these sizes shall be omitted from the mixture.

PLACEMENT

Stones shall be placed by equipment suitable for handling material of the sizes required. The cover stone shall be placed a minimum of two layers thick. Stones shall be placed by means of a bracket or strip. End dumping will not be permitted. Stone shall not be dropped from a height greater than three feet.

GRADES

Cover stone and toe stone shall be placed to the grades (neat lines) shown on the drawings, within a tolerance of 0.5 foot above grade and 0.5 foot below grade, measured perpendicular to the neat lines. The intention is that the stone protection shall be built to at least the neat lines, the outer surfaces shall be reasonably even and present a uniform appearance and that extreme ranges in tolerance will not be allowed in surfaces of adjacent stones.

PILING: SHEET STEEL

Shop drawings shall be submitted to the owner for his approval. The Contractor shall furnish two certified copies of all mill reports covering the chemical and physical properties of the steel used in the work.

Steel for sheet piling shall conform to the requirements of ASTM Standard A 328.

Piles, including special fabricated sections, shall be of the types indicated on the drawings and shall be of a design such that when in place they will be continuously interlocked throughout their entire length. All piles shall be provided with standard handling holes located approximately four inches below the top of the pile. Each steel pile shall be free from any kinks and shall not possess camber, twist, or warp of a degree which will, in any manner, prevent easy and ready driving of a pile. The interlock of each pile shall be straight throughout its entire length and shall be of such shape and dimensions as will permit free and easy threading.

PILING TIMBER

Wood piles shall conform to Federal Specification MM-P-371, Type I, Class B, rough-peeled subject to further limitation in this Section of the specifications. The piles shall be treated in accordance with Federal Specification TT-W-571 with creosote by the pressure process. The wood piles shall be treated to refusal with a minimum creosote content of ten pounds per cubic foot. The Contractor shall make provisions for treating in the field, all cuts, holes and abrasions in the creosoted piles. Abrasions and cuts in the piles shall be given two brush coats of the creosote followed by a heavy coat of tar paint. The lengths of piles shall be as called for on the drawings. To provide for "heading" and cutting off square after driving, piles shall be driven within one foot of the depths specified.

PLACING AND DRIVING PILING

Driving equipment shall be a size and type required to drive piling to the required penetration without serious damage to the pile. Piledriving leads shall be marked so as to facilitate counting of the blows. A protective pile cap of approved design shall be employed in driving, when required, to prevent damage to the tops of the piles. Spliced piles shall not be used. All piles shall be driven to the penetration called for where practicable to do so without damage to the piles.

QUALITY CONTROL

The contractor shall establish and maintain a quality control system for all operations performed under this contract to assure compliance with contract requirements and maintain records of his quality control for all operations performed.

The Coastal Zone Management Act passed by the U.S. Congress in 1972 with its 1976 amendments establishes a national interest in the effective management, beneficial use, protection, and development of the coastal zone by providing assistance and encouragement to coastal states to develop and implement management programs. The addresses for the Great Lakes States coastal zone management offices are listed below. Questions concerning individual state programs should be addressed to the property owner's respective state office.

Illinois
Division of Water Resources
Illinois Department of Transportation
10th Floor
300 North State Street
Chicago, Illinois 60610

Michigan
Coastal Management Program
Department of Natural Resources
Division of Land Resource Program
P.O. Box 30028
Lansing, Michigan 48909

New York
Division of State Planning
Department of State
162 Washington Avenue
Albany, New York 12231

Pennsylvania
Division of Outdoor Recreation
3rd and Reilly Street
Harrisburg, Pennsylvania 17120

Indiana
State Planning Services Agency
143 West Market Street
Indianapolis, Indiana 46204

Minnesota
State Planning Agency
801 Capitol Square Building
St. Paul, Minnesota 55155

Ohio
Department of Natural Resources
1930 Belcher Drive
Columbus, Ohio 43224

Wisconsin
State Planning Office
B-130 One West Wilson Street
Madison, Wisconsin 53702

Successful management of the coastal zone's resources also depends upon local participation through development of a management plan or strategy by individual property owners when they consider shore protection. An individual's management strategy would consist of evaluating the need for shore protection, selecting suitable techniques to provide structural or non-structural erosion control considering other uses of the shore area, and formulating and then implementing a plan. This pamphlet has presented information on techniques that may be used to provide shore erosion control. It must be understood; however, that some of these techniques alter littoral processes and may have either adverse or beneficial effects on other shore uses.

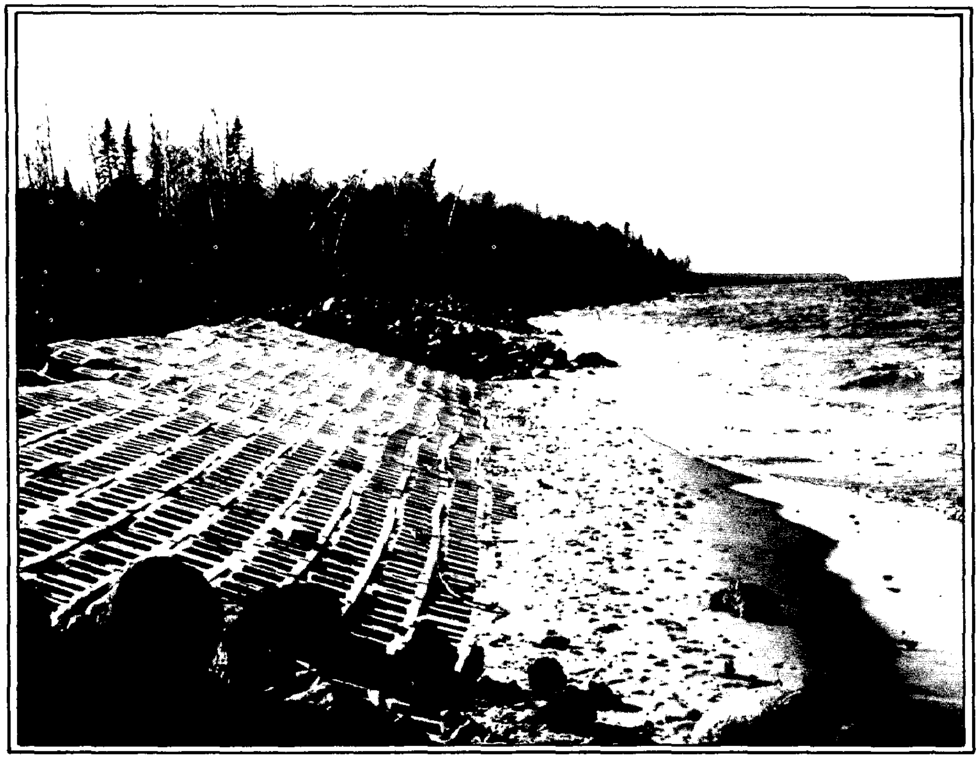
For example, revetments and bulkheads protect only the land area behind them and afford no protection for adjacent beach areas. Erosion in front of these structures may be increased, and if a recreational beach is to be maintained in front of them, additional beach erosion control devices may be necessary.

Although groins or an offshore breakwater may provide additional beach area at the structures, it is often at the expense of the downdrift shoreline. Groins and offshore breakwaters may cause recession of the shoreline downdrift, because the supply of sand to the downdrift shoreline is reduced by the accumulation at the structures. In contrast, beach nourishment provides effective protection without altering the recreational values of the shoreline.

The Corps of Engineers and several Great Lakes states have been involved in a number of demonstration and research projects to develop low-cost practical means of shore protection. Demonstration sites are discussed below, with accompanying photographs, and the locations are shown on the Great Lakes map on page 6. Contact the agency listed for specific information.

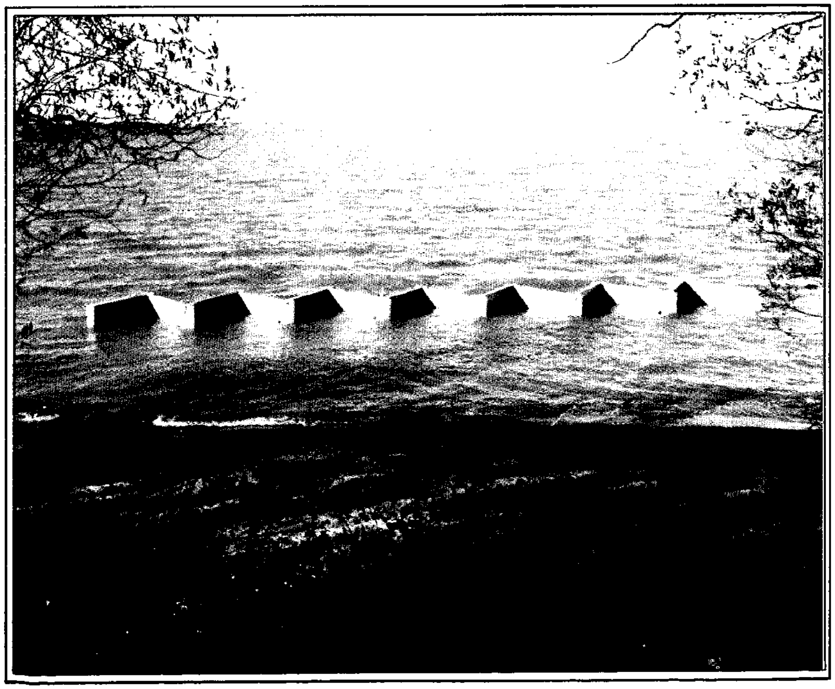
In response to increased concern for the loss of public and private lands caused by shoreline erosion and the resulting environmental and economic damage, Congress authorized Section 54 of the Water Resources Development Act of 1974, Public Law 93-251. This Section, also known as the Shoreline Erosion Control Demonstration Act of 1974, provides that a 5-year program be developed to demonstrate low-cost means to prevent and control shoreline erosion. Two sites were selected on the Great Lakes, one at Port Wing, Wisconsin, in the St. Paul District; and the second at Geneva State Park, Ohio, in the Buffalo District. The projects are scheduled for construction during the fall of 1978. Following that time, the projects will be available for the public to observe their effectiveness. The Port Wing project is shown in the illustration on the right and the Geneva State Park project is shown on the following page.

The types of structures proposed for Port Wing are steel H-piles with railroad ties placed and secured between the piles; a revetment of scrap tires filled with sand, backfilled with granular material; and three different sizes and types of concrete blocks laid on granular material. At each end of the protection and between each demonstration structure, rip-rap sections will be used to prevent possible failure of the structures due to flanking and to prevent failure of one structure from influencing the adjacent structure. Vegetation will be used on the graded slope above the structural measures to stabilize the slope and prevent soil erosion.



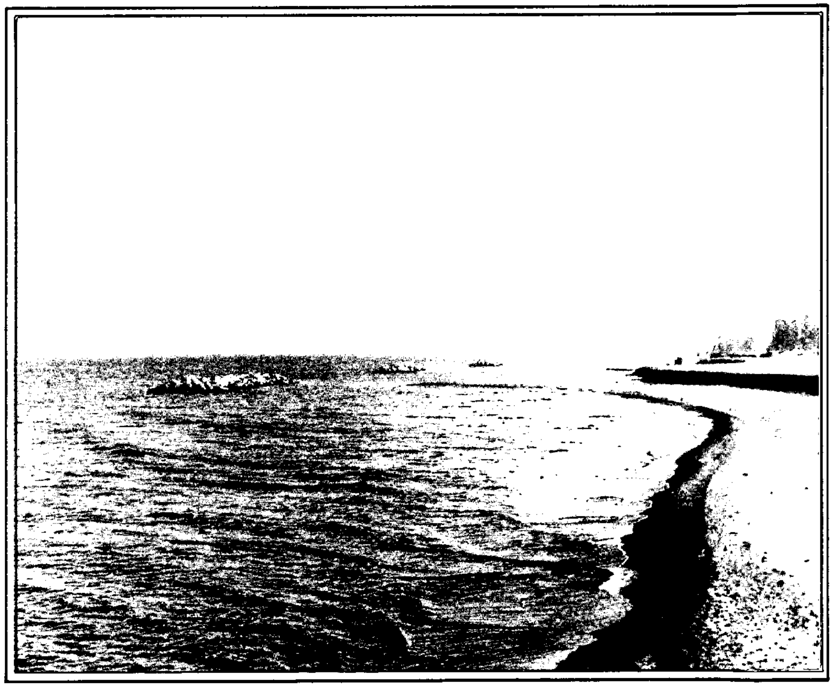
Demonstration project at Port Wing.

Three types of offshore breakwaters of various construction are proposed for the Geneva State Park site. The types of structures are gabions and two types of pre-fabricated concrete units. Also, vegetation will be incorporated into the project to assist in stabilizing a portion of the sand trapped by the structures.



Demonstration project at Geneva State Park

Three experimental offshore stone breakwaters with beach fill placed behind the structures were constructed between May and July 1978 by the Buffalo District on Beach 10, Presque Isle, PA; Lake Erie. The breakwaters were constructed to obtain information and data which can be used in determining whether breakwaters would be the best permanent shore protection method for the eroding areas of Presque Isle.



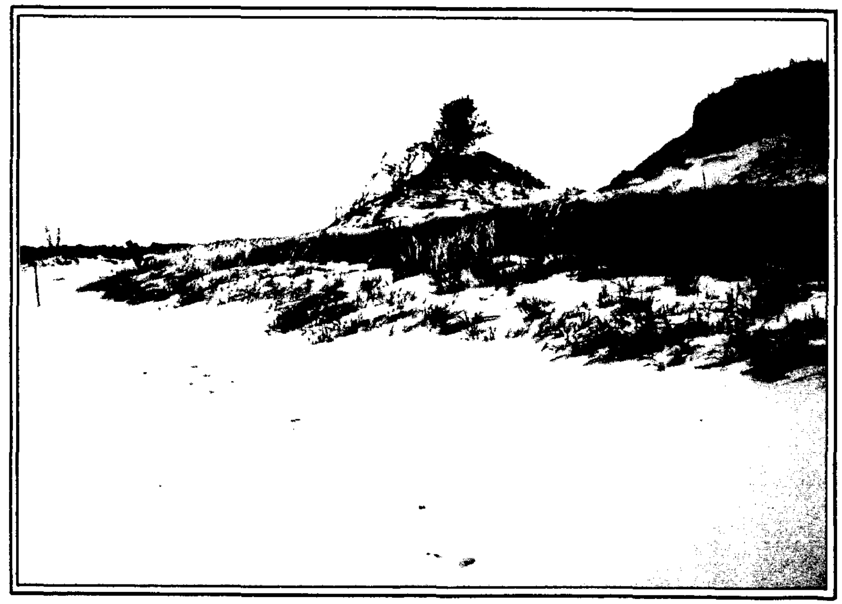
Breakwaters at Beach 10, Presque Isle.

Public Law 520, 71st Congress and Public Law 166, 79th Congress, authorized the United States in cooperation with the states, to study and report on means for the stabilization of beaches at shoreline areas. To demonstrate the effectiveness of using beach grasses to build and stabilize dunes on the shores of the Great Lakes to protect against erosion, a demonstration site was selected on the Pennsylvania and Michigan shorelines. The two sites are described in the following paragraphs.

A vegetative dune-building demonstration project was planted in May 1977 west of Beach 10, Presque Isle, PA using American Beach grass and prairie sand reed. The project was planted by the U.S. Army, Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Va.; in cooperation with the North Central Division and the State of Pennsylvania.

A vegetative demonstration project similar to the one at Presque Isle was planted in 1977 at Ludington State Park, MI by the Corps of Engineers in cooperation with the State of Michigan.

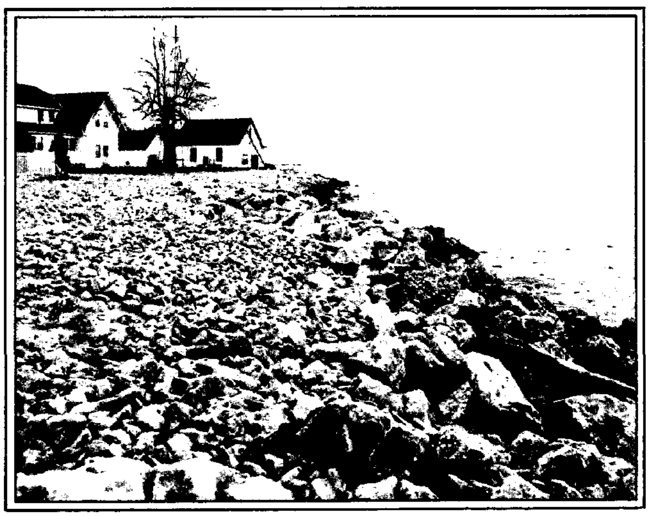
Vegetation site at Presque Isle



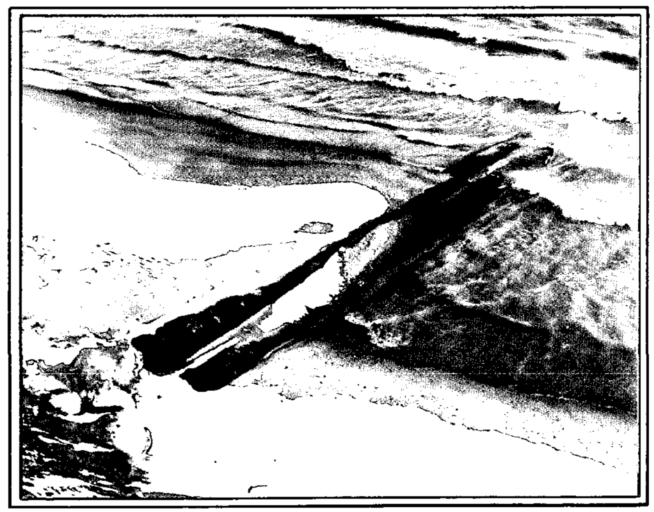
Vegetation site at Ludington State Park

The Michigan Department of Natural Resources, Bureau of Water Management, implemented under the authority of Act 14 of the State Public Acts of 1973, a Demonstration Erosion Control Program in 1974 to demonstrate both innovative and conventional means of shore protection. All of the devices installed were intended to be low cost, and the costs varied from about $50 to $100 per foot. Reports have been prepared to describe the program and to report on the results achieved during the first three years of the study. The most recent report is entitled "The Michigan Demonstration Erosion Control Program in 1976." Photographs of several of the demonstration sites are shown here.

Gabion groin, 3 miles south of Port Sanilac, MI.



Rock revetment at Tawas Pt. MI.



Sand-filled nylon tube groin 3 miles south of Port Sanilac, MI.

GLOSSARY OF TERMS

ALONGSHORE — Parallel to and near the shoreline; same as LONGSHORE.

BACKSHORE — That zone of the shore or beach lying between the foreshore and the coastline and acted upon by waves only during severe storms, especially when combined with exceptionally high water.

BEACH PROFILE — A side view of the zone along the shoreline that extends landward from the water's edge to the toe of a dune or bluff.

BREAKWATER — A structure protecting a shore area, harbor, anchorage, or basin from waves.

BULKHEAD — A structure or partition to retain or prevent sliding of the land. A secondary purpose is to protect the upland against damage from wave action.

CROSS SECTION — A vertical section (profile) of the surface, the ground, and/or underlying material, which provides a side view of the structure or beach (see beach profile).

CURRENT, LITTORAL — Any current in the littoral zone caused primarily by wave action, e.g., longshore current, rip current.

CURRENT, LONGSHORE — The littoral current in the breaker zone moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.

DATUM, PLANE — The horizontal plane to which soundings, ground elevations, or water surface elevations are referred. Also REFERENCE PLANE.

DEEPWATER WAVE — Waves which develop in water of sufficient depth that they are not influenced by the friction of the lake bottom.

DIFFRACTION (of water waves) — The phenomenon by which energy is transmitted laterally along a wave crest. when a part of a train of waves is interrupted by a barrier, such as a breakwater, the effect of diffraction is manifested by propagation of waves into the sheltered region within the barrier's geometric shadow.

DOWNDRIFT — The direction of predominant movement of littoral materials.

EROSION — The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or wind.

EQUILIBRIUM — A state of balance or equality of opposing forces.

EXPEDIENT — A device used in an emergency such as a structure intended to provide shore protection during the period of high lake levels.

FORESHORE — The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash) and the water's edge, that is ordinarily traversed by the uprush and backrush of the waves.

FUNCTIONAL LIFE — The period of time the structure performs as intended. Performance can be expressed in terms of benefits obtained versus the cost of maintenance.

GROIN (British, GROYNE) — A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

HEADS OF BAYS — In the approximate center of a bay between the two points or headlands which form the bay.

IMPERMEABLE — Not permitting passage of water.

LITTORAL — Of or pertaining to a shore.

LITTORAL DRIFT — The sedimentary material moved in the littoral zone under the influence of waves and currents.

LITTORAL TRANSPORT — The movement of littoral drift in the littoral zone by waves and currents. Includes movement parallel (longshore transport) and perpendicular (on-offshore transport) to the shore.

LITTORAL ZONE — In beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the breaker zone.

LONGSHORE — Parallel to and near the shoreline.

NEARSHORE (ZONE) — In beach terminology an indefinite zone extending seaward from the shoreline well beyond the breaker zone. It defines the area of NEARSHORE CURRENTS.

NEAT LINES — Lines on drawings which establish tolerances for construction.

PERMIT — A document issued by the Department of the Army expressing the assent of the Federal Government, so far as concerns the public rights of navigation and the general public interest, for the accomplishment of certain works on or adjacent to navigable waters of the United States.

PILE — A long, heavy timber or section of concrete or metal to be driven or jetted into the earth or lakebed to serve as a support or protection.

PILE, SHEET — A pile with a generally slender flat cross section to be driven into the ground or lakebed and meshed or interlocked with like members to form a diaphragm, wall, or bulkhead.

QUALITY CONTROL — A standard of comparison which assures a minimum of deviation from the standard.

REFLECTED WAVE — That part of an incident wave that is returned seaward when a wave impinges on a steep beach, barrier, or other reflecting surface.

REFRACTION (OF WATER WAVES) — The process by which the direction of a wave moving in shallow water at an angle to the contours is changed. The part of the wave advancing in shallower water moves more slowly than that part still advancing in deeper water, causing the wave crest to bend toward alignment with the underwater contours.

REVETMENT — A facing of stone, concrete, etc., built to protect a scarp, embankment, or shore structure against erosion by wave action or currents.

RIPRAP — A layer, facing, or protective mound of stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment; also the stone so used.

SEAWALL — A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. See also BULKHEAD.

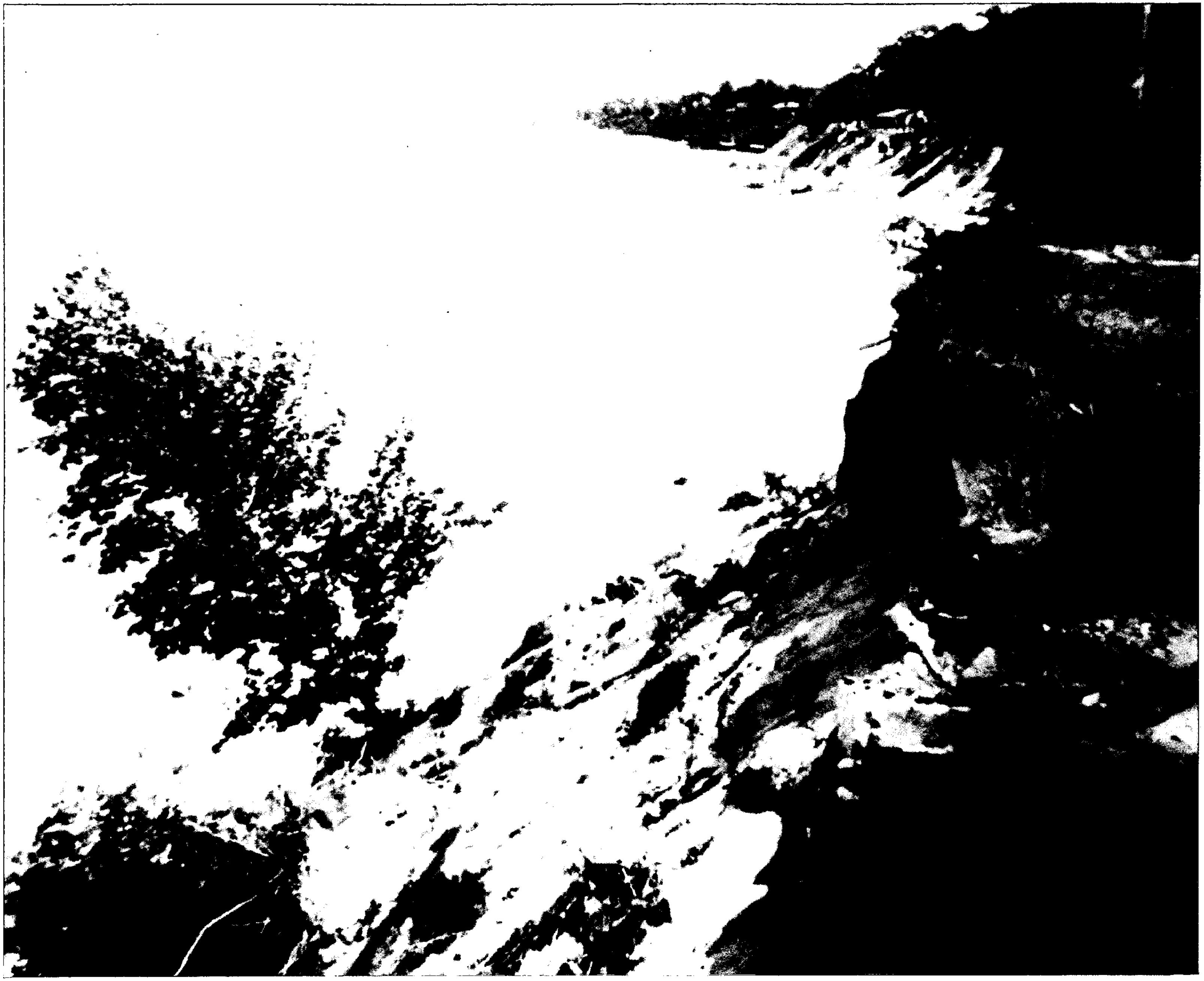
SPECIFICATIONS — A detailed description of particulars, such as size of stone, quality of materials, contractor performance, terms, quality control, etc.

STILLWATER LEVEL — The elevation that the surface of the water would assume if all wave action were absent.

UPDRIFT — The direction opposite that of the predominant movement of littoral materials.

VOID RATIO — The volume of space or gaps to the volume of the area of the structure such as a stone revetment.

WIND SETUP — (1) The vertical rise in the stillwater level on the leeward side of a body of water caused by wind stress on the surface of the water. (2) The difference in stillwater levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water.



DEPARTMENT OF THE ARMY CORPS OF ENGINEERS NORTH CENTRAL DIVISION